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# EARTH-CURRENTS

By B. W. CURRIE

## INTRODUCTION

THE establishment of the first telegraph systems almost a century ago led to the discovery of natural electric currents flowing in the surface layers of the earth. Occasionally the intensity of these currents fluctuated so rapidly that the transmission of messages was impossible. At the same time geomagnetic disturbances and auroral displays were frequently observed. As a result it was decided correctly that the disturbing currents on the telegraph lines originated from a varying potential difference of terrestrial origin between the grounded points in the telegraph circuits. Once telegraph and cable systems covered large areas of the earth's surface it was found that these earth-current disturbances were a widespread and simultaneous phenomenon definitely associated with magnetic storms and auroral activity.

The existence of earth-currents had been suggested by both Sir Humphry Davy and Faraday before their accidental discovery. The former proposed in 1821 that the observed variations of the compass-direction were caused by earth-currents of varying intensity, while the latter attempted in 1831 to detect the converse effect, a varying earth-current induced by the variations of the earth's magnetic field. Although the discovery of earth-currents and subsequently of their association with geomagnetic disturbances gave considerable weight to their speculations, immediate attempts were not made apparently to distinguish by observation between these two possible processes.

The first systematic observations of earth-currents were made at Greenwich Observatory from 1865 to 1867. During the remainder of the nineteenth century measurements were made at a number of European observatories, usually for short intervals of time, the measurements at Berlin, Germany, from 1883 to 1891 being the most notable exception. The records from Ebro Observatory, Spain, are the longest that are available at the present time, the observations having been continued with little interruption since 1910. Most of the credit for initiating systematic registrations of earth-currents at a number of magnetic observatories with a view to eventually correlating earth-current and geomagnetic phenomena belongs to the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, although other organizations in Sweden and the United States have made significant contributions to the available data during recent years.

An earth-current measuring system was installed by the Carnegie Institution at their magnetic observatory near Watheroo, Western Australia, in 1923. Three years later a similar system was put in operation at their observatory near Huancayo, Peru. In co-operation with the U.S. Coast and Geodetic Survey, earth-current registrations were started by them at the magnetic observatory near Tucson, Arizona, in 1931. Again in 1932-33 during the second International Polar Year they assumed the responsibility for the earth-current observations made at College, Alaska, and loaned similar equipment to the Canadian Meteorological Service for use at Chesterfield Inlet, District of Keewatin. The data from these two stations are of especial interest since both were located in high latitudes close to the zone of maximum auroral frequency.

## Measurement

The registration of earth-currents appears at first sight to be simple in comparison with that of most geophysical phenomena. Two metal electrodes sunk in the earth and connected by an insulated cable through a galvanometer of suitable sensitivity are sufficient to measure the potential difference due to the earth-current flow between the two electrode sites. For continuous recording a beam of light is reflected to a clock-driven photogram from a mirror attached to the galvanometer suspension. To determine the direction and the relative magnitude of the earth-current flow at any instant two such systems are

required, one set of electrodes located preferably on a north-south line and the other set on an east-west line. Unfortunately the metal-in-earth electrodes cause other potential differences than those due to the desired earth-current flow to be recorded.

Dissimilar chemical, moisture and temperature conditions at the electrodes always result in unbalanced contact potentials that give a current flow through the galvanometer. As long as these electrode conditions can be kept constant or allowed to change only very slowly the fluctuations of potential from the recorded mean potential can be attributed to the varying earth-current flow. This is accomplished usually by placing the electrodes from four to eight feet below the surface where the effects of rapid changes of temperature and moisture conditions at the surface are small. Precautions must be taken also adequately to insulate the junction of the electrode and the cable or wire running to the galvanometer, and to prevent insulation leaks between the cable and the ground. Unsuspected inhomogeneities may exist below the surface that not only distort the direction of the current flow but affect the recorded potentials between one set of electrodes more than those of the other set since for a given earth-current density the recorded potential depends on the resistivities of the surface layers of earth. The result is computed directions for the current flow that are anomalous to the region as a whole. Wherever possible an earth-resistivity survey should be made of the region covered by the electrode-systems to detect such inhomogeneities of structure. Failure to avoid these sources of error means another contribution to the already bulky volume of data that are of uncertain utility.

At Chesterfield Inlet, where the writer of this note had his first experience at measuring earth-current potentials, the electrodes were sunk in pockets of sand in the exposed bedrock. They were horizontal, cross-shaped grids, each arm measuring about 8 ft. by 2.5 ft. and containing approximately 30 ft. of ¼-inch lead wire. Insulated wire laid along the surface connected the electrodes to the galvanometers. Thermal and chemical potentials between the electrodes were surprisingly small and caused no difficulty. Large increases of the contact-resistances at the electrodes occurred during the winter, the normal resistance of about 2000 ohms increasing to the order of $10^6$ ohms. Electrostatic charges that developed apparently on the wires from the electrodes to the galvanometers during heavy snow-drift,

led to a considerable loss of record. A detailed account of the difficulties of making earth-current measurements in this region may be found in Volume II of the "Canadian Polar Year Expeditions 1932-33", which has been published recently by the Division of Meteorological Services of Canada.

The earth-current potentials in this region are subject to irregular oscillations of large amplitude and short period. Changes in the potential that exceed one volt per kilometre in less than five minutes are not unusual. The top curve in Figure 1 shows the recorded north-

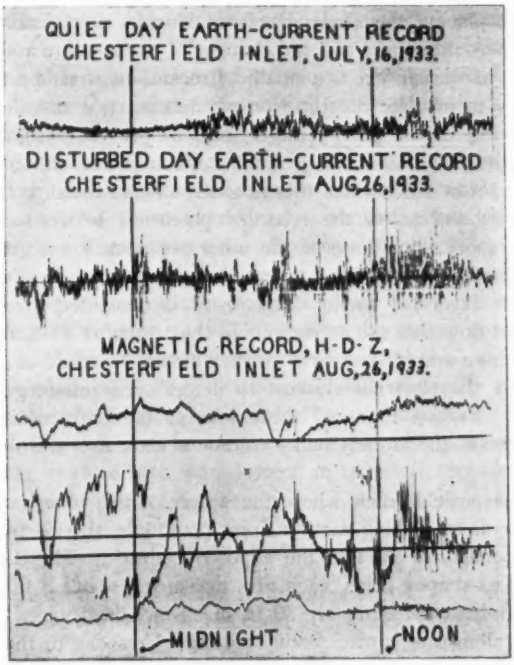


FIG. 1.—Record of the northward component of the earth-current potentials on a quiet day, and a comparison of the record of magnetic elements with the record of the northward component of the earth-current potential on a disturbed day.

ward component of the earth-current potential for a magnetically quiet day, July 16, 1933, while the middle curve shows the northward com-

ponent for a disturbed day, Aug. 26, 1933. The large amplitude of the oscillatory disturbances in comparison with the diurnal variation should be noted. To obtain a measurable record of the diurnal variation (possible only on quiet days) the galvanometer circuits were operated at a sensitivity which meant a considerable loss of record on disturbed days because of the rapid movement of the recording light-beam. A complete photographic record of earth-current

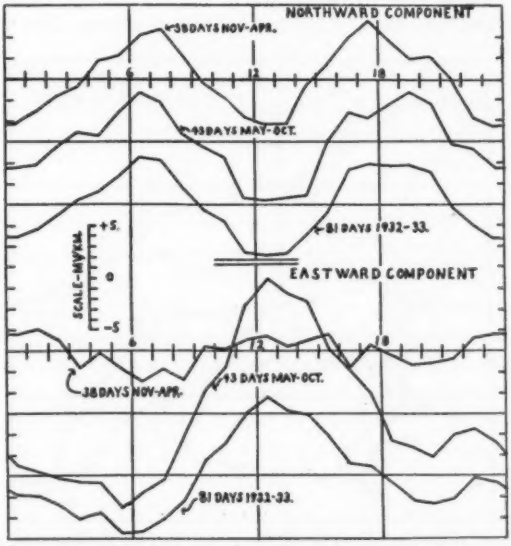


FIG. 2.—Mean diurnal variations of northward and eastward components of earth-current potential gradients on quiet days at Chesterfield Inlet.

potentials could have been obtained only by means of a duplicate installation using low-sensitivity galvanometer circuits, and photograms driven at three or four times the normal speed in order to give a more open time-scale.

*Analysis of Records.* So far most earth-current studies have been confined to the diurnal variation of the potential gradient (expressed in millivolts per kilometre). Records for days with little disturbance are selected, and are scaled for the mean potential during each hour-interval. Then, the mean potential for each day is computed and is subtracted from the corresponding hourly values to find the diurnal variation of the potential for the day, since, as stated previously, the

steady or unvarying portion is due entirely to thermal and chemical effects at the electrodes. Whenever the potential difference is such as to indicate a component of the current flow eastward or northward it is assumed usually to be positive.

Figure 2 shows the mean diurnal variation of the northward and eastward components of the potential gradients on quiet days at Chesterfield Inlet (1932-33). The northward component is characterized by a double wave with minima at approximately local noon and local midnight, and by a slight increase of the range during the day

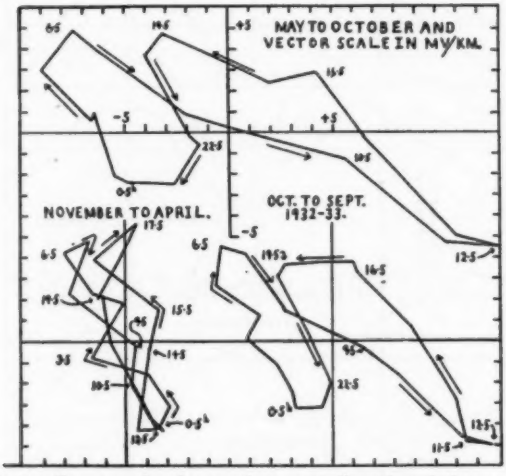


FIG. 3.—Vector diagrams showing earth-current diurnal variation on quiet days at Chesterfield Inlet.

and during the summer; and the eastward component by a double wave of small amplitude in the winter months that differs in phase from the northward component by about 180°, and by a single wave of large amplitude during the summer months. This single wave of large amplitude is of especial interest, since its occurrence suggests a faulty recording circuit. However, a similar wave was observed simultaneously at College, Alaska,[1] and this is good evidence that the recording circuits were functioning properly at both places.

The direction and magnitude of the earth-current flow can be visualized more clearly by means of diagrams similar to those shown in Figure 3 for Chesterfield Inlet. Corresponding values of the mean hourly components of the potential gradients are used to plot the

terminal points of a set of vectors that give the mean hourly direction and that are proportional to the mean hourly magnitude of the earth-current flow. The confusion that would exist if each vector were drawn is avoided by joining successive points by straight lines. From the diagrams for Chesterfield Inlet it can be seen that both the magnitude and the direction of the earth-current flow are constantly changing during the day, and from season to season. At approximately local midnight and local noon the earth-current changes from a southeasterly to a northwesterly direction, and then again reverses direction at about $6^h$ and $17^h$ during the winter and $6^h$ and $19^h$ during the summer. During the winter the average direction of the variations is approximately along the magnetic meridian through Chesterfield Inlet (11° west of north), and during the summer northwest by west.

## Periodic Variations

The relationship between earth-current data of this type and the simultaneous geomagnetic changes is still to be determined. If the magnetic changes are produced directly by the earth-currents the diurnal variation of the component of the magnetic force at right angles to the current should correspond closely to the diurnal variation of the potential gradient in the direction of the current. On the other hand, if the earth-currents are induced by the observed magnetic changes, the correspondence should be between the rate of change of the magnetic force and the potential gradient, the earth-current flow at right angles to the component of the magnetic force disappearing whenever the latter ceases to change. Data distinguishing beyond question between these two processes have yet to be found. A preliminary study of the observations made at Chesterfield Inlet show a better agreement in the latter case. Apparently the relationship is a complex one that involves the reaction of the earth-current on the magnetic field.

Considerable evidence of a qualitative nature in support of a physical connection between the two has been discovered. Bartels and Rooney[2] on comparing the magnetic and earth-current records for two successive days that were magnetically unusually quiet with those for normally quiet days at Watherhoo Observatory, Australia, found a significant parallelism in the changes of both. Rooney[3] for the three-year period 1932-34 at Tucson, Arizona, has reported a decided parallelism between the quiet day diurnal-variation records

of earth-current flow and the diurnal variation of the magnetic elements for both winter and summer. Since Tucson is located in the transition-belt where the diurnal variation of magnetic dip and intensity change from a high-latitude to an equatorial type with the apparent motion of the sun northward, a corresponding seasonal change of the earth-current flow is at least an indication that the same primary agent is responsible for both.

With the increased amount of observational data that is now available Gish[4] has been able to construct a picture of the current-systems flowing in the surface layers of the earth. He finds eight great electric eddies located in middle latitudes, four in the northern hemisphere and four in the southern hemisphere, symmetrically placed on either side of the equator with centres about equally spaced in longitude and lying along a parallel of latitude near the tropics of Cancer and Capricorn respectively. Four more eddies with centres in the Arctic are indicated by the very inadequate data. Four corresponding eddies probably exist in the Antarctic. All these eddies are fixed relative to the sun, apparently rotating around the earth once each solar day and moving northward and southward with the sun during the year. In equatorial latitudes the current flow is parallel to the equator, while in middle latitudes the flow is toward the equator during the middle of the day and away from it during the night.

Prospects of relating these particular earth-current eddies to the system of electrical circulations in the upper atmosphere that accounts for the observed mean diurnal geomagnetic changes on magnetically quiet days are remote. Little is known, as yet, concerning the effects of the distribution and configuration of the oceans and continents and of the electrical properties of the earth to a depth of at least several hundred kilometres on the earth-current eddies. Experimental work by the Bell Telephone Laboratories[5] on earth-currents along the eastern part of the United States showed a pronounced directive tendency, apparently of either a region of high resistivities paralleling the coast-line or of the Atlantic Ocean. Nippoldt[6] considered the observed earth-currents as a phenomenon entirely divorced from geomagnetic phenomena, and expressed the opinion that at coastal stations the current flows parallel to the coast. It should be noted here that the aforementioned work of the Bell Telephone Company is not in agreement with this opinion.

## Non-periodic Disturbances

A comparison between earth-current records and the corresponding geomagnetic records for magnetically disturbed days shows unquestionably that some type of physical relationship exists between them in this case. When one is disturbed, the other is also disturbed. For Chesterfield Inlet, where the magnetic elements are exceptionally disturbed, corresponding electrograms and magnetograms can be selected without difficulty from the coincidences of disturbed conditions on them. The records of the magnetic elements on Aug. 26, 1933, at Chesterfield Inlet are shown at the bottom of Figure 1. A casual examination shows that both are disturbed simultaneously. However, the earth-current disturbance in contrast with the magnetic disturbance is highly oscillatory. This difference may be due to the moving parts in the magnetograph having an inertia which permits only the recording of the envelope of the rapid magnetic variations.

Earth-current disturbances or storms apparently occur simultaneously everywhere on the earth, the greatest amplitudes being observed in the regions of maximum auroral activity. Figure 4, which is copied from a study of the earth-current measurements at College, Alaska, by Rooney and Sherman,[1] is an example of a disturbance of large amplitude that was recorded at College at the same time as an isolated auroral display was observed there, and which appeared also on the records from Tucson, Arizona, and from Huancayo, Peru, but with an amplitude which decreased with the increased distance from College. Considerable agreement was found between aurorae and earth-current disturbances at College, coefficients of linear correlation from 0.71 to 0.76 resulting from the use of different measures of disturbance.[7] Oscillatory disturbances and moving types of aurorae seemed to show the highest degree of correlation. A less-detailed study of the Chesterfield Inlet earth-current and auroral records showed that periods of great earth-current activity were also periods of great auroral activity and that both were manifestations of increased magnetic activity over the earth.

The widespread occurrence of earth-current storms at the same times as magnetic storms, and the large amplitudes of the disturbances and the high correlation between the disturbances and observed aurorae in latitudes close to the zone of maximum auroral frequency

agree well with the picture of the electrical disturbances in the upper atmosphere that explains many of the features of magnetic storms. Part of the current-system necessary to produce magnetic storms is an intense flow of current around the earth in the auroral zones.

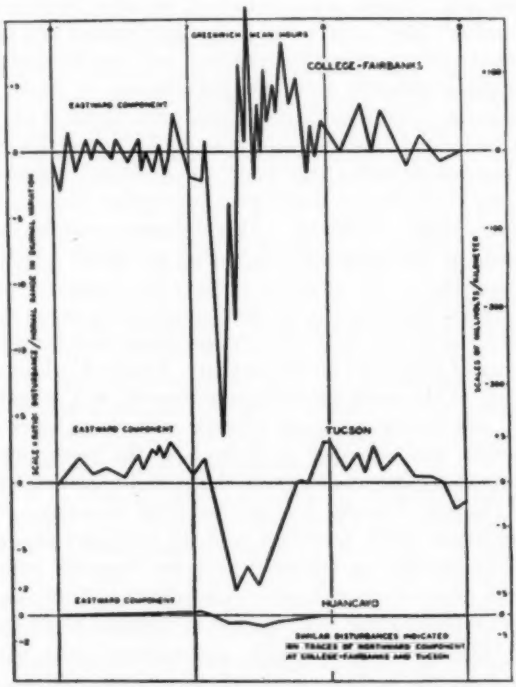


FIG. 4.—Earth-current disturbances at College-Fairbanks, Tucson and Huancayo—accompanying isolated auroral display at College-Fairbanks, 7 to 8 Greenwich mean time, Dec. 31, 1932 (after Rooney and Sherman).

These zones are belts in the atmosphere at least 100 km. above the earth's surface and located approximately 23° from the geomagnetic poles. They become highly conducting by the influx of particles which give rise to the auroral light, and so are able to carry the intense currents required to explain some of the characteristics of magnetic storms. Presumably an auroral display is a visual indication of a

varying conductivity in the upper atmosphere which results not only in marked changes of intensity of the current-flow but to some extent in its form and position in the atmosphere,—changes which make themselves evident by a disturbance of the magnetic elements and by earth-currents induced in the surface layers of the earth.

Still another indication of the existence of a relationship between earth-currents, observed magnetic changes and the electrical condition of the upper atmosphere should be mentioned. Bright chromospheric eruptions on the sun are usually accompanied by the cessation of the reflection of high-frequency radio signals from the ionized regions of the atmosphere, and by the simultaneous disturbance of both the magnetic and earth-current records.[8]

## Conclusions

A great need exists at the present time for an increased number of earth-current stations in polar and equatorial latitudes,—preferably in connection with magnetic and auroral observatories. With the data from these stations it would be possible to relate the periodic variations of the earth-currents to that of the earth's magnetic field, to map accurately the lines of earth-current flow over the earth's surface, and to study the effects of aurorae on both earth-current and geomagnetic disturbances. Eventually it might be possible to deduce structural differences extending to considerable depths below the surface of the earth from the distortion of the lines of earth-current flow.

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# FOLK-LORE OF THE CALENDAR*

By Wade Poston, Jr.

TO say that the delays which have characterized every phase of calendar reform have been largely the offspring of tradition is not an original statement, nor a novel one. The justification for remaking it here, and for proposing to enlarge upon it, is a belief that the deterrent powers of tradition have never been fully realized or explored. Much space has been given to the reasonableness of calendar reform, but little to the unreasonableness of the factors which stand in its way.

If at first we attribute these delays to national prejudices or to religious practice, we must soon revise that opinion when we have seen the readiness and the interest with which the majority of great governments and great religions have accepted the plan. Or, if we are to place them at the doors of indolence and indifference, we must make the assumption (undoubtedly false) that no one has ever felt the inconvenience of the calendar in figuring his accounts, in estimating his contracts, or in planting his crops. In order to explain the delays we must look beyond these factors to a subtler influence.

For the calendar is much more than a clock that measures the years. It is a great sieve. Through its meshes the thick liquor of 200 centuries has flowed, while each year has left its residue of black magic—its myths, fables, and foolish hyper-orthodoxies. Thus have the errors of the past remained to clog the future.

This result is assignable to an outstanding peculiarity of the measuring system. In reality, time is a straight line; but for us it wears a circular aspect. We speak of next week-end, and of last Thursday. January *returns* once more. The years *roll* on.

The basic confusion, which is easily seen once the problem is stated, is between time itself and certain natural phenomena, such as the earth's revolution around the sun and its rotation on its own axis, which are used to measure time. This point hardly needs extension. What is more important for the present consideration is that this circular conception of time furnishes the means by which

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superstitions become attached to the calendar, gradually transforming it from an instrument to an institution. As such, it gives both an occasion and a logic to the reviviscence of past events and becomes an integral part of all anniversaries and celebrations.

With these facts in mind, it is not hard to see how the calendar comes to have a special kind of quasi-sacredness. Indeed, when one counts the cords of tradition that fasten the calendar to the past, he no longer wonders at its permanence and resistance to change. For instance, the unhampered measures of space and weight within the last 200 years have been widely revised over almost the entire world; but, within the last 2,000 years not a single major change has been made in the calendar. The slightest modifications have met with unbelievable opposition. Upon the introduction of the slight changes of the Gregorian calendar, London mobs rioted in the streets—as recently as 1752! Some of the feeling of those times has been set down by Longfellow in the following passage, wherein March is made to tell the fearsome results of meddling with the calendar:

> "I Martius am! Once first, and now the third!
> To lead the year was my appointed place;
> A mortal dispossessed me by a word,
> And set there Janus with the double face.
> Hence I make war on all the human race:
> I shake the cities with my hurricanes,
> I flood the rivers, and their banks efface,
> And drown the farms and hamlets with my rains."

If we seek less literary, but more spontaneous links between superstition and the calendar, we need only delve into folk-lore to discover them by the thousands! The following rhyme on St. Paul's Day (January 25) is representative of many others:

> "If St. Paul's day be fair and clear,
> It does betide a happy year;
> But if it chance to snow or rain,
> There will be dear all kind of grain;
> If clouds or mist do dark the skie,
> Great stores of birds and beasts will die;
> And if the winds do flie aloft,
> Then war shall vexe the kingdome oft."

Better known, perhaps, is the St. Swithin's Day weather superstition (July 15):

"St. Swithin's Day, gin ye do rain,
For forty days it will remain;
St. Swithin's Day, and ye be fair,
For forty days 'twill rain nae mair."

The following lines are the corollary:

"St. Bartlemy's mantle wipes dry
All the tears that St. Swithin can cry."

A question which can be aptly put at this time is the extent to which these ancient humbugs influence present-day attitudes toward the calendar. The spirit undoubtedly remains, making account for that enigmatical prejudice—the feeling that it is "bad" to change the calendar. But does the letter also remain? At least, it is remarkable how many newspapers deem it worth while to call attention annually to the incorrectness of the St. Swithin's Day prophecy, and, even more so, to the groundhog's sally on February 2.

This latter superstition is, among Americans, perhaps the best known of all. Although its early history is obscure, it seems definitely to follow from one of the often-repeated, Old English sayings:

"A' the month o' the year
Curse a fair Februeer."

—which was, possibly, a more or less sound piece of farming advice. Later, this thought was narrowed down to Candlemas Day—the day of purification and the most significant in the month. The fact that February derives its name from the Latin *februa,* or "means of purification" made the transition easy, and, in its superficiality, is probably typical of the growth of many similar delusions. This can be seen in the following rhymes:

"If Candlemas Day be dry and fair,
The half of winter's to come, and mair;
If Candlemas Day be wet and foul,
The half o' winter's gone at Yule."

The groundhog is an addition of recent times: American farmers of the Middle Atlantic States are thought to be the originators. According to this superstition, if the groundhog sees his shadow when he makes his supposititious exit on Candlemas Day, he is frightened and returns to his hole. The result is that winter continues for

six weeks longer. However, if the day is cloudy and shadowless, the groundhog stays on the surface; and the winter is over.

The mechanics of this addition are not clear. It may be that the hibernation of the groundhog is disturbed by the mid-winter thaw, causing a few specimens to be flooded out by sunny weather. At any rate, considerable importance is attached to the belief in rural America. Even the sage *New York Times* annually devotes to it a not-too-serious column.

Another peculiar superstition—one that has made an entire business unnecessarily periodic—is the common idea that it is injurious to eat oysters in a month whose name is not spelled with an "R"; a saying credited to Butler's *Dyet's Dry Dinner,* 1599. The French have this:

"Boir eau point ne devez
Au mois ou 'r' trouverez."

which can be rendered as, "You should never drink water in a month in which you can find an 'r'."

Not only days of the month, but also days of the week—particularly Friday—carry a burden of superstition. It is considered unlucky to start anything new on Friday, especially to undertake a voyage or to be married. With some justice, Friday is looked upon as a notoriously bad day for financial panics; but this fact is traceable not to any occult power, but to the close approach of the week-end holidays. Friday the thirteenth is considered extremely unlucky by those who still lay a certain emphasis on "luck." An interesting reaction to this superstition has occurred in the formation of several "Friday the Thirteenth Clubs," whose members meet on the day indicated, and who walk under ladders, fill the room with black cats, drop horseshoes, and perform other rites in defiance of superstition. The very fact that such organizations do exist emphasizes how widespread are the beliefs concerning Friday.

This superstition apparently dates back to medieval times and to the acceptance of "God's Friday" (or Good Friday) as the day on which Christ was crucified. Likewise, the belief concerning the number thirteen relates to the Last Supper. Originally, it applied only to situations where thirteen persons were seated at the same table—one was to die within a year. Later, the conception of thirteen

as an unlucky number underwent a process of growth; and, because of associations already established, it was readily linked to the calendar and to Friday in particular.

A somewhat lighter tradition attaches to Monday, which is as famous for being "blue" as is Friday for being "black." Monday is the historical washing day. As such, it has been enshrined in the nursery rhyme: "This is the way we wash our clothes; All of a Monday morning." But this apparently harmless doggerel was recently assigned by a national convention of laundryowners as one of the chief causes of detrimental peak-loads in the early part of the week.

There is hardly any need to go further with this list. Indeed, this article has examined only the more curious superstitions and not necessarily the most powerful. Such celebrations as Hallowe'en, All Fools' Day, and St. Valentine's Day are cases in point. Many specific areas have local traditions of great importance: i.e., the Mardi Gras at New Orleans, or the May-Day beauty bath at St. Arthur's Seat, Edinburgh.

No less important than the general beliefs just discussed are individual traditions, such as birthdays and various family anniversaries, which always in the past have been a main source of objection to calendar changes. George Washington, for example, is said to have been greatly confused by the change from the Julian to the Gregorian system. It is now customary to consider that he was born on February 22, in the year 1732. However, according to the calendar then in use, the date of his birth was February 11, 1731. Washington was doubly affected: first, by the dropping of 11 days from the calendar, and second, by the moving of the new year from March 25 to January 1. He continued to celebrate his birthday on February 11, although in signing important documents he indicated the disparity by giving both dates.

These problems are far from being matters of the past. They must be faced by both the present and the future. It is to be hoped that, at the next opportunity to introduce The World Calendar, some five years hence, a programme of education will have nullified the force of false tradition and made possible the adoption of this sensible timing system.

# THE NEW TELESCOPE DRIVE AT THE HARVARD OBSERVATORY

By Herbert E. Hanson*

MODERN astronomical practice requires that the telescope drive should not only operate with the highest obtainable precision, but that it be also rugged in construction, simple in operation, and flexible in adjustment.

There are many electric drives, but most of them can be classified under one of the following three types.

1. *The synchronous motor connected to a constant-frequency power-supply.*

This is perhaps the simplest type, but it has only one rate which cannot be changed, the accuracy of which is determined by the frequency available. Such a drive is used successfully at the Harvard Observatory with a short focus camera; for more accurate work, however, it is not satisfactory.

2. *The synchronous motor connected to a frequency-controlled power-supply.*

At the McMath Hulbert Observatory[1] the motor is connected to an alternating-current generator whose frequency is controlled by a vacuum-tube oscillator. The rate is uniform and can be changed at any time by the observer on the observing platform. On large telescopes this is a decided advantage, but in observatories which have many telescopes it becomes complicated and expensive, as a separate generator and frequency-control system are needed for each telescope.

3. *The Gerrish drive or pendulum-controlled mechanism.*

The Gerrish drive has been in use at the Harvard Observatory for many years. It has, however, one serious objection: once out of

*Reprinted from the June number of the *Review of Scientific Instruments*, 1939.

[1]R. R. McMath, Pub. Michigan Observ. 7, No. 1, 42-48 (1937).

order, it requires the attention of a person who thoroughly understands its operation to locate the trouble properly, because of the many contacts and relays used. Fig. 1 is a schematic drawing of this drive. The operation is as follows.

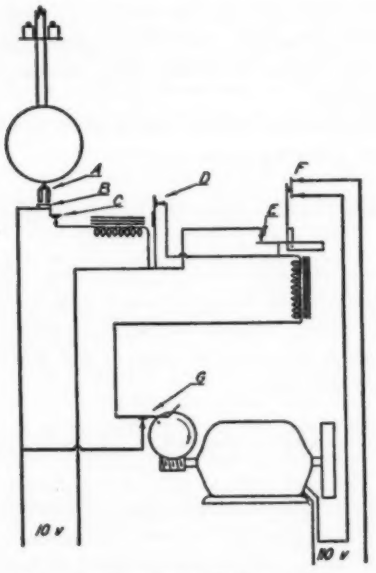


FIG. 1.—The Gerrish Telescope Drive.

A permanent magnet *A* is attached to the bottom of the control-clock pendulum. As it swings, the small armature *B* mounted on the contact spring is lifted, thus breaking the delicate platinum contact *C*. This de-energizes the relay magnet and allows the contact *D* to close. When this contact closes, the armature of the power relay is pulled down closing contact *E*, which shunts contact *D*. The power relay is thus locked in position, regardless of further signals from the control clock. The power contact *F* closes simultaneously with the shunt contact *E*, and the motor runs until contact *G* is opened by a pin in the timing gear. When the pin opens contact

*G*, the circuit of the power relay is broken, thus shutting off the current to the motor. The motor would stop except for the inertia of the motor armature, which closes contact *G* immediately after it is opened. This momentary opening of *G* opens the shunt contact *E*, thus leaving the power relay open and in position for the next impulse from the clock. It is this pause which governs the speed of the motor. If the voltage is high or the load decreased, the pause is lengthened; if the voltage is low or the load increased, the pause is shortened. The ratio of timing-gear speed to that of the motor should be such that with the timing gear turning one revolution per second (if a one-second clock is used), the motor would be running at about 80 per cent. of its full speed. If the motor speed is much greater than 80 per cent., the amount of control is lessened; if it is lower than this, the motor will tend to start with too much inertia and will synchronize at a harmonic which will be much above the desired speed, and hence the rate will be more or less irregular. To smooth out the power impulses, a fly-wheel is attached to the motor shaft which reduces speed fluctuation to a negligible amount.

The Gerrish drive is very flexible; the rate can be changed at any time to allow for atmospheric refraction or tube flecture. To change the rate it is only necessary to increase or decrease the load on the pendulum shelf.

4. *Harvard's new telescope drive.*

In the past few months we have tested at the Oak Ridge Station of the Harvard Observatory a new drive which has all the advantages of the one described above, without the complicated electrical circuit. It is sketched in Fig. 2, and the operation is as follows.

The magnet *A* on the pendulum opens platinum contact *C*, thus allowing armature *H* to drop so far away from the magnet poles that it cannot be pulled back by the clock signals after it is once released. As it drops, the power contact* *F* is closed, causing the driving motor to start. The motor also drives the cam *J* (by a gear of the same ratio as in the drive described above). The cam *J* returns the arma-

*Mercoid switches (Mercoid Corporation, Chicago, Illinois) have been successfully used for this purpose.

ture *H* to its original position, where it is held until the circuit is again broken by the control clock.

The old Gerrish drive has five contacts; failure of any one of these will cause an upset in the rate. The new arrangement has but two contacts which are much simpler to adjust. It is also less expensive to build and can be installed on any size telescope. In its

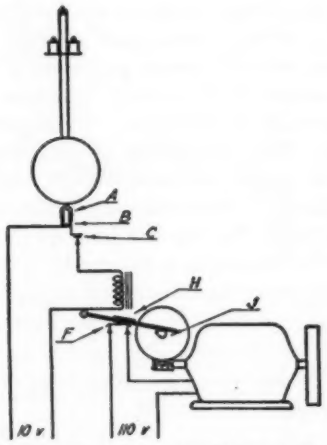


FIG. 2.—The New Telescope Drive at Harvard.

present use on the 61-inch telescope, the motor is coupled to the driving worm through a differential gear. This arrangement allows the use of a small auxiliary motor for accurate slow-motion guiding. The slow-motion guiding motor is operated from the eye-piece by means of a small manual, through relays, in order to avoid any danger of shock to the operator.

More recently the new drive was adapted for use entirely from the alternating-current lighting line, without the necessity of any rectifying apparatus. This, of course, should be of great advantage to observatories not equipped with direct current.

Harvard College Observatory,
Cambridge, Mass.

## REVIEW OF PUBLICATIONS

*An Introduction to Modern Geometry*, by L. S. Shively. John Wiley & Sons, New York. Price $2.00.

As Athena sprang full-armed from the forehead of Zeus, so for most people, geometry was conceived perfect and complete in the mind of Euclid. But much has been done since his time and every book which recognizes this fact serves to remove some of the cobwebs and to vitalize this most fascinating branch of mathematics. It was early in the seventeenth century that the great "modern geometers" Pascal and Desargues laid the foundations of projective geometry, in which the idea of length plays no part. Later, in the nineteenth century, it was just this problem of length or *congruence* which stirred the geometrical world anew.

Professor Shively in his book "An Introduction to Modern Geometry" has endeavoured to do justice to Pascal and Desargues, but as much as may be in the framework of Euclidean geometry. He only mentions a conic in passing, and interprets every theorem with reference to a circle. While he makes the distinction between the projective and metrical points of view, this might have been further clarified. If the idea of a correspondence had been somewhat amplified, in particular in chapter 9, where cross ratio is introduced, involution in chapter 10 would have appeared in better perspective.

The book is well written and contains a wealth of interesting material; chapter 5 on the less known properties of triangles, and chapter 7 on inversion are both valuable. There is a welcome emphasis placed upon ruler and compass constructions in chapter 11, whose importance can hardly be over-stressed.

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G. DE B. ROBINSON.

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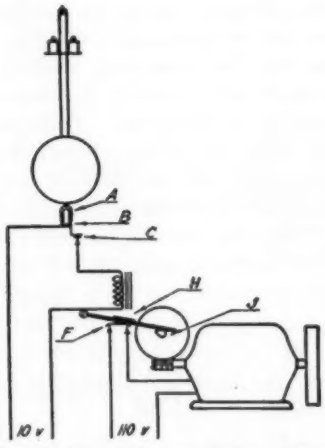


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*Tables for Converting Rectangular to Polar Co-ordinates*, by J. C. P. Miller. 11 pp., 6 x 10 ins. Scientific Computing Service, Ltd., London, 1939. Price 2 shillings.

A few years ago, under the direction of Dr. L. J. Comrie, formerly Superintendent of H.M. Nautical Almanac Office, the Scientific Computing Service was founded in London. This institution undertakes any form of scientific, statistical or technical calculations, by a staff of professional computers equipped with a complete range of modern calculating aids. Part of their service includes the publication of modern tables for specific purposes.

The present little 4 figure table by Dr. Miller is for the purpose of converting from rectangular co-ordinates, $(x, y)$, to polar co-ordinates $(r, \theta)$.

Then $r = \sqrt{x^2 + y^2} = x\sqrt{1 + \frac{y^2}{x^2}} = x\sqrt{1 + k}$; and $\theta = \tan^{-1} k$ in the case where $|y| < |x|$.

In the table $\sqrt{1+k^2}$, $\theta$ in radians, and $\theta$ and $90-\theta$ in degrees are given as a function of $k$.

For the opposite case, and depending on the signs of $x$ and $y$, rules are given for determining the values of $\theta$.

This table should be very useful to computers who perform large numbers of transformations of co-ordinates.

F. S. H.

*Beyond Yonder*, by Oliver Justin Lee. 169 pp., 5 x 7 ins. Boston, Mass.: Chapmas and Grimes, Inc., 1939. Price $2.50.

In this small and interesting book Professor Lee, director of Dearborn Observatory, shows for the ordinary reader, the continuity of the logic of the measurement of distances. He passes from everyday units of distance down to the submicroscopic units used in measuring wavelengths of light, and upward to the size of the earth, the distances of the sun, the stars, and galaxies other than ours.

The book is written in a very informal style, and many quotations, familiar and unfamiliar, are included. A few diagrams are found in the text, while an appendix contains several diagrams, the simpler formulae, and examples. A number of the sketches and

plates may add interest, but rather less instruction than might be desired.

Books such as this, which stress the methods and ideas involved in the formation of our present astronomical knowledge are much more thought provoking than those which are content to describe merely the present picture of the universe. Professor Lee has succeeded in presenting much of this logic without making a book that is in any way formidable to the ordinary reader.

F. S. H.

# NOTES AND QUERIES

**Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.**

## Summer Activities at Victoria

The summer programme of Victoria Centre was very successful. Thanks to the vigorous initiative of the president, Mr. Robert Peters, and the whole-hearted support given to him by the officers and council, attendance at this, the eighth series of "Summer Evenings with the Stars" has exceeded all records. A notably successful feature was the use of mimeographed diagrams, prepared by Mr. K. O. Wright, of the stars forming the catch figures of the constellations. Some seventy of these were distributed each week and recipients were instructed for their own interest to compare the diagram with the constellation, to number the stars shown on the diagram in their order of brightness and add an estimate of their colours. At the next meeting the proper values were announced.

The local radio station, CFCT, has very kindly given time for a series of weekly talks under the general subject of Astronomy as a Hobby.

Finally, by co-operation of the Chamber of Commerce and the Park Authority, a series of weekly outdoor demonstrations free to the public has been held in Beacon Hill Park. The telescopes were set up in a roped-off enclosure and spectators were shown the moon, planets and some double stars and nebulae. These meetings seem to be creating remarkable interest, queues four abreast waiting their turn to see. Victoria and Victoria Centre of this society have reason to be proud of the self-sacrificing and effective work that is being done there to popularize astronomical knowledge. It is a splendid example.

H. B. B.

## Rigollet's Comet

The discovery of this comet was mentioned in this Journal for July-August. Since then the comet has been observed at a number of observatories; as the observed arc has become longer, increasingly accurate orbital elements have been possible. As early as August 3 Mr. Leland Cunningham, of the Harvard Observatory, suggested

that the preliminary (parabolic) orbits indicated that this "new" comet might be a return of Caroline Herschel's comet, 1788 II. The later elements tend to confirm this suggestion. A comparison of orbits is given below.

| | Comet 1788 II | Comet Rigollet 1939 | |
|---|---|---|---|
| $T$ | Nov. 20.36854 | Aug. 9.28121 | Aug. 9.4649 U.T. |
| $\omega$ | 30° 26′.3 | 29° 02′.4 | 29° 17′.9 |
| $\Omega$ | 352 29 .1 | 355 30 .0 | 355 07 .3 |
| $i$ | 64 28 .1 | 64 14 .1 | 64 12 .0 |
| $q$ | 0.7574 | 0.74986 | 0.748459 |
| | Parabolic orbit by Miss Palmer (Yale). | Parabolic orbit by Panofsky and Miss Scott (Lick). | Elliptical orbit by Maxwell and Mrs. Kastner (Berkeley). $e$ 0.973498 $P$ 150 years |

It might be noted that Margaretta Palmer, discussing the comet of 1788, in 1921, determined a number of orbits, and concluded that the inaccuracies of the observatories and the short period of visibility made it impossible to determine the orbit with any degree of certainty. However, a parabolic or slightly elliptical orbit (P=8500 years) satisfied the observations equally well; while a hyperbola, or an ellipse of shorter period (P=3000 years) did no serious violence to the observations. This comet has not previously been classified as other than a non-periodic comet.

### Tuttle's Periodic Comet

This comet, period 13.5 years, was rediscovered as an 18th magnitude object by Dr. Jeffers, at the Lick Observatory, August 12, 1939. The comet was further observed August 18. It is satisfactory that this faint comet has been rediscovered. Its position agrees fairly well with the position predicted, after applying perturbations by Jupiter and Saturn, but indicates that the time of perihelion passage might be changed from November 10.1 to 10.8.

### Moving an Observatory

In order to secure freedom from city lights, or better meteoro-

logical conditions, or to make room for expanding neighbours, it has been frequently necessary to move observatories. Usually at such times the instruments are moved, and the occasion is used to secure a new building and possibly new equipment. On occasion the buildings have been taken apart and reassembled at the new site. What is probably the first record of the moving of a major observatory as a unit is contained in *Science* for October 13, 1939.

Dearborn Observatory of Northwestern University is being moved 600 feet south and east to clear the site for the erection of the new Technological Institute. Under the direction of Dr. Oliver J. Lee, chairman of the department, astronomers at the university have stored the telescope lenses in underground vaults, lashed the telescope to the walls and moved most of the delicate instruments out of the building. The 125-ton brick pier on which the telescope rests will be moved with the building. Using 700 jacks, each of 25-ton capacity, the entire structure has been raised about three feet, placed on rollers, and is being taken away on tracks, using two teams of horses and a tractor. Test borings indicate that the new site of the observatory is directly over an old creek bed, which will give the building a firm foundation on a dense clay substratum.

### Harvard Observatory, 1839-1939

This summer Professor Shapley called attention to the fact that this year might well be considered the centenary of the Harvard College Observatory. While the study of astronomy had been actively pursued at Harvard many years previously, and while the present site and main building were not secured till several years later, it was in October, 1839, that the first Harvard Observatory was inaugurated, at Dana House. An interesting account of the early history of the observatory is contained in the first volume of the Harvard Annals.

Under a series of noted directors, the Bonds, Winlock, Pickering, and Shapley, this observatory has steadily expanded in staff, buildings, equipment and range of researches undertaken. An excellent and comprehensive book was published by Professor Bailey in 1931, entitled "History and Work of Harvard Observatory, 1839 to 1927." This book is highly recommended to those interested in the story of the development of astronomy at Harvard from pre-observatory days up to the last decade; the remarkable expansion of the observatory since that time has already made this book somewhat out of date. The completion of the Bloemfontein

(South Africa) and Oak Ridge (Mass.) stations, each with a 60-inch reflector, the new Astrophotographic Building at Cambridge, the increasing importance of the graduate school, and the inauguration of the Summer Conferences on astronomy make this the most active decade of the observatory's first century, and are a tribute to the genius of the present director.

F. S. H.

WHEN THE EARTH SPLIT

To the query which follows the Editor is unable to supply a reasonable answer and requests readers to send in references to papers or books relating to the subject. In considering this question one must remember that the earth is a globe and the depth of the ocean is small compared to its width. The deepest place, as far as known to the writer, is near Porto Rico (44,000 feet) in the West Indies. Near Celebes in the East Indies the depth is 34,000 feet. Also volcanic action is comparatively very shallow—merely pustules in the earth's crust. These problems of the formation of the surface features of the earth must be considered together.

There are a few things this amateur astronomer would like to know about that "split" in the earth which caused the Atlantic ocean to form. Every atlas he can get his scissors into has been cut out like a picture puzzle to prove over and over again that the east side of the Atlantic (Europe and Africa) is a counterpart of the west side (North and South America). When the Atlantic has been cut out, and the two sides placed together, they fit each other like the torn edges of a piece of paper. The only reference to this I can find in the JOURNAL is in a review of the book issued a few years ago entitled "Our Mobile Earth," but that book, upon inspection, mentions the "split" somewhat casually. The astonishing thing about this dramatic event is that up to about twenty-five years ago few, if any, persons appear to have noticed how the two hemispheres join together to make one huge continent. Something happened in the dim past which affected the history of the world tremendously. Had the "split" not occurred, Columbus would have had no discovery to make, and Napoleon would not have been thwarted by the English Channel. Britannia would have had no chance to rule the waves, and Liberty itself would not have been able to set up its standards in a New World. A "voyage of discovery" in the Library of the Royal Astronomical Society and the Public Library, instead of disclosing a wide literature on this subject, showed that it has been rather neglected. Geologists confine their work to world conditions *after* the event, and astronomers seem to either take it for granted that everybody can see what took place or else they think their work starts with the earth as a whole. Seeing that neither of these professionals appear to wish to tackle the subject, this amateur rushes in where others may

fear to tread, and proclaims as the result of his investigations (in libraries) that the "split" was likely the result of a stupendous explosion when the earth was in a molten condition (but with a surface considerably cooled, or caked) and that the explosion took place on the "opposite" side of the globe, so that the ejection of the molten matter from the earth caused the great continent to split; thus causing the hollow which later became the Atlantic ocean. The matter ejected perhaps became the Moon, and the great hole in the Pacific ocean, which is the deepest great hollow on the globe, is very likely the place from which the matter was discharged. The earthquake zone around the shores of the Pacific rather suggests that the disturbance is not yet over, and the suggestion that the continents of the western hemisphere are still moving slightly westward, and that the moon itself is leaving the earth as a result of that far-distant (in time) expulsion, or that some of the molten matter may have formed the asteroids, or become an outer moon of Jupiter.

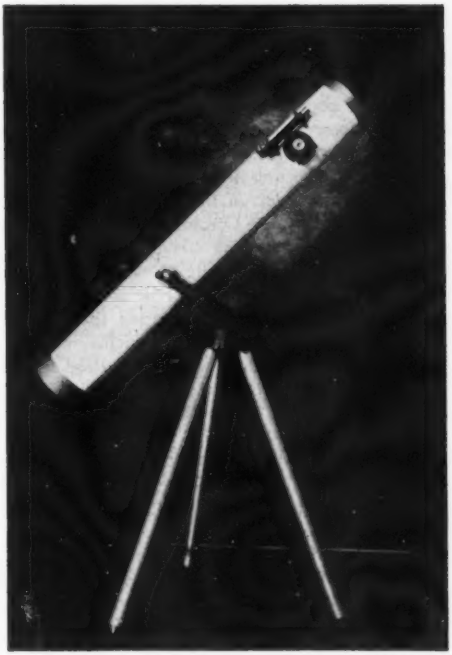
All these interesting speculations fall naturally into place after we have cut up a few atlases and studied the situation fully without any professional guidance. However, there is one explosion on the earth's surface which is well authenticated —and if we can have a small volcanic eruption we can also have a big one— the volcanic island of Krakatoa in the East Indian Islands, near Java, which lost its mountain top in 1883 in the most violent earthquake and volcanic upheaval recorded by man. Where the island and mountain top used to be, there is now nothing but ocean, a thousand feet deep. The sound of the explosion was heard 3,000 miles away, and the air waves it caused went around the world three times before they quieted down. The island was uninhabited, but the tidal waves of the ocean rose a hundred feet, went to the neighbouring shores and drowned 36,000 people. The sky was darkened by dust for thousands of miles, and red sunsets were seen for a long time in all parts of the world, caused by the dust particles in the air.

F. T. S.

### Amateur Telescopes

The surprising growth of the construction of small telescopes by amateur workers appears to continue unchecked. This "phenomenon" is pleasing to observe and is highly to be commended. Much of the success of the movement must be credited to Mr. Albert G. Ingalls through his monthly contributions to the *Scientific American* and his two admirable books on telescope making. These are almost indispensable to the person who undertakes to grind a mirror or build a mounting. Mr. Ingall's writings have an intimacy and a sparkle which render them attractive. There is a certain exhilaration in attempting a difficult task and a real satisfaction in bringing it to a successful completion; and there are few owners of these home-made instruments who have not had their interest in astronomy quickened and enlarged.

The immediate cause of these thoughts was the receipt of a photograph along with a letter from Mr. Gordon Shaw, at one time secretary and then president of the Victoria Centre of the R.A.S.C. The photograph, reproduced herewith, shows a small reflector. The diameter of the mirror is six inches, the yoke and head of the



Mr. Shaw's Six-inch Reflector.

mounting are of cast aluminum, and the tripod legs are of duraluminum. The mounting is strong and rigid and the entire instrument weighs thirty-five pounds. In partnership with a local mechanician, Mr. Shaw has undertaken the production of a number of these telescopes, and some members who cannot make their own instruments will find it advantageous to communicate with Mr. Shaw.

C. A. C.

# MEETINGS OF THE SOCIETY

## AT OTTAWA

*February 9, 1939.*—In the Lecture Hall of the Victoria Memorial Museum, Ottawa. Mr. John McLeish, the immediate past president of the Centre, introduced Mr. R. M. Motherwell of the Dominion Observatory, Ottawa, who spoke about "The Two Hundred Inch Telescope."

The lecturer first gave a brief history of the discovery and development of the telescope, beginning with the discovery by Lippershey, in 1608, of the magnifying properties of certain combinations of spectacle lenses. The work of Gregory, Newton, Cassegrain, Hadley and Herschel in connection with the development of the reflecting telescope was outlined and a brief reference made to the standard types of reflecting telescopes. Then followed an outline of the experimental work carried out on the production of the great mirror by the General Electric Co. and by the Corning Glass Co. The General Electric Co. experimented with fused quartz but could not get a disc of the required size. The contract for the disc was finally given to the Corning Glass works and after some two years of careful research the 200-inch disc was poured.

The construction of the furnace for producing the required sixty tons of molten glass, the method of pouring, the construction of the mould and the pouring oven and the annealing furnace were all outlined rather fully.

The grinding and polishing of the mirrors was briefly sketched and then the problems involved in selection of a suitable site and the construction of a practical type of mounting were described.

Lantern slides were used throughout and two reels of motion pictures kindly loaned by the Corning Glass Works and the Westinghouse Co. of Pittsburgh showed the actual pouring of the molten glass into the mould and the construction of part of the mounting.

The popular interest of the lecture was shown by the large attendance, and also by the number of questions asked. Mr. McLeish thanked the speaker and after the National Anthem was sung declared the meeting adjourned.

*March 15, 1939.*—Mr. R. Meldrum Stewart, Dominion Astronomer, introduced the speaker of the evening, Mr. John A. Marsh, M.P. for Hamilton West.

Mr. Marsh said that there were two ways of approaching astronomy. There was the one man who would pick up a meteor and say, "Yes, that is a meteor". Another would say, "Yes, that is a meteor, a visitor from the outer space. What story has it to tell of the life and death of one of the stars? How does it help to unfold to me more of the truth of the universe?"

This is a wonder world in which we find ourselves. The very air we breath may have supplied breath to such great persons as Socrates or Caesar, and in the intervening centuries the same molecules of oxygen and hydrogen

may in turn have been part of rain drops and at one time been a part of the beauty of the lily! Truth and beauty are to be found everywhere. There is no conflict between religion and science. The only conflict is between unlearned theologians and narrow scientists.

There followed a number of pictures of eclipse expeditions, some showing Mr. Marsh's late father, some showing father and son. Then pictures of the moon which had been taken by the speaker. The audience was delighted with the ease with which Mr. Marsh presented the figures and facts of our solar system, and the awe and respect with which the truths of nature were held by him. From the solar system, the audience was given glimpses of distant objects, globular clusters, and the ring nebula in Lyra, all of which revealed the great guiding Force operating through this great universe.

At the conclusion of the lecture, Mr. Stewart thanked the speaker, and after the playing of the National Anthem, the meeting was adjourned.

*March 29, 1939.*—In the Lecture Hall of the Victoria Memorial Museum, Ottawa. Dr. T. L. Tanton introduced the speaker of the evening, Dr. J. F. Heard of the David Dunlap Observatory, University of Toronto, whose subject for the evening was "Current Research at the David Dunlap Observatory."

The lecturer described the observatory and its equipment with particular reference to the 74-inch reflector. Attention was drawn to the importance in observatory work of sustained research, often of a routine nature, along lines which provide astronomy with data for a more complete understanding of the structure and workings of the universe. This type of general programme was illustrated by references to the D.D.O. determinations of radical velocities of stars and Dr. Helen Hogg's work on globular clusters.

As examples of research on particular objects of interest, Dr. Heard cited Dr. P. M. Millman's recent spectrophotometric study of Mars, which resulted in the conclusion that the greenish areas on Mars are not so coloured because of the presence of chlorophyll; and the curious behaviour of the star Gamma Cassiopeiae which, from variations in its light, colour and spectrum, is interpreted as having in recent years behaved as a nova in that it ejected a gaseous envelope which has now largely dispersed.

Dr. Tanton expressed the thanks of the gathering to the speaker, and at the conclusion of the National Anthem, the meeting was adjourned.

M. M. Thomson, *Secretary.*

## AT VANCOUVER

*February 14, 1939.*—The sixtieth regular meeting of the Vancouver Centre was held at 8.15 p.m. in Room 200 of the Science Building, University of British Columbia.

President McDonald introduced the speaker of the evening, Prof. Walter H. Gage of the Department of Mathematics, University of British Columbia, who spoke on "Exceptions to the Rule in Astronomy." This subject, of course, involved the statement of the rules themselves. These rules in turn, recalled

the names of their discoverers: Copernicus, Brahe, Kepler, Galileo, Newton, Herschel; that brilliant assembly of genius which laid the foundations of modern science. Surely this company of men were exceptions to the rule that all men are born equal.

After this introduction the speaker turned to a more detailed study of exceptions to the rule in astronomy. We learned of Adams and Leverrier explaining the minor perturbations in the motion of the planet Uranus and discovering Neptune in the process. We learned of exceptional stars, of red giants and white dwarfs and were entranced by speculations on the evolution of the stars. The mysteries of space: the structure of galaxies and supergalaxies, the occurrence of binaries and star clusters, the red shift; these facts which at present fit no pattern occupied our rapt attention.

Mr. Gage thus filled in ninety minutes of most informative entertainment. The three aspects of scientific discovery, the mysteries or exceptions to the rule, the logical strokes of genius and the resultant more comprehensive conception of our universe were skilfully combined into an informative and informal talk. The lecture was illustrated by free hand sketches.

After the discussion Messrs. H. W. Fowler and A. Outram expressed the opinion of the meeting when they described the address as one of the most informative and interesting that they had heard. The meeting stood adjourned on the motion of the president.

*March 14, 1939.*—The sixty-first regular meeting of the Vancouver Centre was held at 8.15 p.m. in Room 200 of the Science Building, University of British Columbia.

The speaker of the evening, Dr. C. S. Beals of the Dominion Astrophysical Observatory at Victoria, was introduced by the president of the Vancouver Centre. After quickly removing any possibility of ambiguity in the topic of the lecture, "The Age of Giants", Dr. Beals introduced his audience to the scientific atmosphere of the Renaissance. In turn he described the contribution to science made by da Vinci, Copernicus, Brahe, Bruno, Galileo, Kepler, Descartes, Huyghens and Newton. The lecture was of particular interest since Dr. Beals had evidently studied the history of science during the Renaissance with great care. Many interesting sidelights and humorous details of the lives of these men and their contemporaries were included by the speaker.

The lecture was very completely illustrated with lantern slides which included portraits of these giants of the golden age, their note books, observatories and instruments. Dr. Beals had undoubtedly spent much time and thought in searching records and collecting his slide material, even from the resources of the Dominion Astrophysical Observatory. Certainly this was no tiring recital of the known events in the lives of these fathers of modern science but a subtle presentation of the spirit of their age.

During the discussion, Dr. Beals found it necessary to remind the members of the tremendous technical advances made since the Renaissance. The audience joined in hearty applause for a very interesting and erudite lecture.

A. M. Crooker, *Secretary.*

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